SOC Needs for optimal active or passive Li-ion balancing techniques

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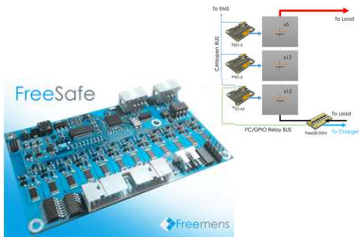
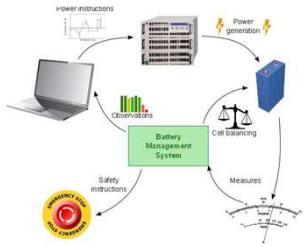
Battery Management Systems

Battery management systems (BMS) are used in batteries with series connected cells to ensure the **battery safety**, the **optimization of the battery answer** to any power requests and the **access to reliable data on the battery state**.

One of the most critical point to complete these functionalities is the accuracy of the implemented indicators used to estimate the battery state.

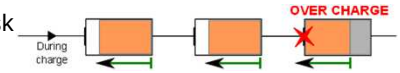




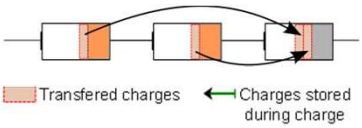
Cells disparities

Battery indicators such the *State Of Charge* (SOC) or *State Of Health* (SOH) are usually expressed at battery level for cells with homogeneous behaviors [1]. However this assumption is invalid when the cells present disparities in their initial characteristics and especially under aging conditions [2].

Example 1: increased risk of cell overcharge



Example 2: charges transfer for State Of Charge equalization



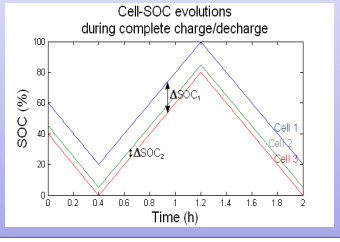
Effective maximum capacity Q_{max_bat} and SOC_{bat}

Q_{cell} denotes the present charge amount stored in the cells, Q_{max} and Q_{max_cell} the initial and the present maximum charge amounts that the cells can store and I_{cell} the current in the cells.

$$SOH_{cell} = \frac{Q_{\max\_cell}}{Q_{\max}} \qquad SOC_{cell}(t) = \frac{Q_{cell}(t)}{Q_{\max\_cell}}$$

1st case study
Cells with the same SOH

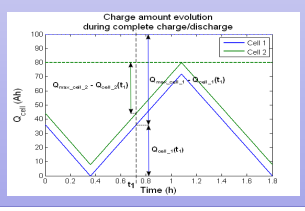
$$\begin{cases} Q_{\max\_bat} = Q_{\max} * SOH * (1 - max(\Delta SOC)) \\ SOC_{bat}(t) = \min_{1 \le i \le N}(SOC_{cell\_i}(t)) * \dfrac{1}{1 - max(\Delta SOC)} \end{cases}$$

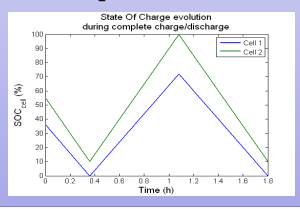


2nd case study
Cells with the SOH_{cell} disparities

$$\begin{cases} Q_{\max\_bat} = \min_{1 \le i \le N}(Q_{cell\_i}(t)) + \min_{1 \le i \le N}(Q_{\max\_cell\_i} - Q_{cell\_i}(t)) \\ SOC_{bat}(t) = \dfrac{\min_{1 \le i \le N}(Q_{cell\_i}(t))}{Q_{\max\_bat}} \end{cases}$$

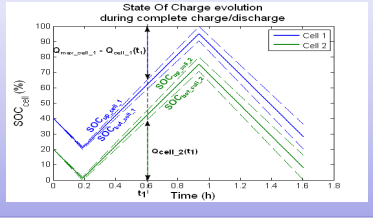
$$\begin{cases} Q_{\max\_bat} = Q_{\max} * \Big[\min_{1 \le i \le N}(SOH_{cell\_i} * SOC_{cell\_i}(t)) \\ \qquad + \min_{1 \le i \le N}\left(SOH_{cell\_i} * \left(1 - SOC_{cell\_i}(t)\right)\right)\Big] \\ SOC_{bat}(t) = \dfrac{Q_{\max} * \min_{1 \le i \le N}(SOH_{cell\_i} * SOC_{cell\_i}(t))}{Q_{\max\_bat}} \end{cases}$$



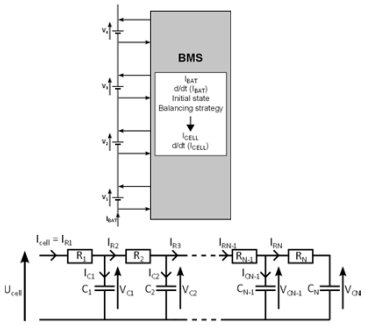


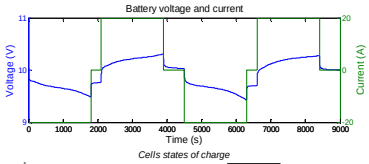
3rd case study
With uncertainties on SOC estimations

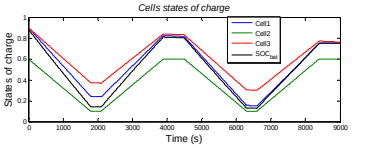
$$\begin{cases} Q_{\max\_bat}(t) = Q_{\max} * \Big[\min_{1 \le i \le N}(SOH_{cell\_i} * SOC_{bot\_cell\_i}(t)) \\ \qquad + \min_{1 \le i \le N}\left(SOH_{cell\_i} * \left(1 - SOC_{up\_cell\_i}(t)\right)\right)\Big] \\ SOC_{bat}(t) = \dfrac{Q_{\max} * \min_{1 \le i \le N}(SOH_{cell\_i} * SOC_{bot\_cell\_i}(t))}{Q_{\max\_bat}(t)} \end{cases}$$

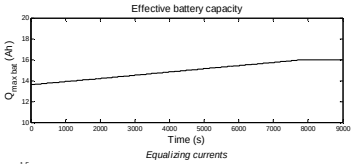


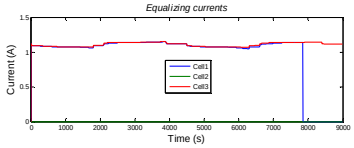
Implementation











Simulation results – Behaviour of a battery composed of 3 cells Of 20Ah and with passive balancing

$$SOH_{cell\_1} = 80\% \quad SOH_{cell\_2} = SOH_{cell\_3} = 100\%$$

1. G. Plett, "Extended Kalman filtering for battery management systems of LiPB-based HEV battery packs. Part 2: Modeling and identification", J. Power Sources 134 (2), 2004, 262–276.
2. M, Dubarry, "Origins and accommodation of cell variations in Li-ion battery pack modeling", Int. J. Energy Res., 2010, 34: 216–231.